NASA Contractor Report 3782

Significant Achievements in the Planetary Geology Program, 1982

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Significant Achievements in the Planetary Geology Program, 1982

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Introduction

The purpose of this publication is to summarize the research conducted by NASA's Planetary Geology Program Principal Investigators (PGPI), Mars Data Analysis Program (MDAP) and Jupiter Data Analysis Program (JDAP) Geology Principal Investigators. The summaries in this document are based on presentations at the fourteenth PGPI meeting held at the U.S. Geological Survey National Headquarters, Reston, Virginia, January 17-21, 1983 and are a digest of the 1983 meeting abstract document (Reports of the Planetary Geology Program - 1982, NASA TM-85127). Important developments are summarized under the broad headings listed in the Table of Contents.

The accomplishments of any science program are a reflection on the people who take part in it. The contents of this document are a testimony to the PGPI's who have produced significant advances in the exploration of space. They represent a group of people dedicated to advancing the frontiers of geology beyond the usual confines of planet Earth.

This document is based upon summaries prepared by session chairpersons at the annual meetings. These contributing authors are listed below:

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Outer Solar System Satellites and Small Planetary Bodies

A. S. McEwen and L. A. Soderblom (USGS - Flagstaff) have identified two classes of volcanic plumes on Io. Large plumes deposit red material over areas about 1400 km in diameter and are probably shortlived (days). Smaller plumes deposit bright white material over areas about 300 km in diameter and are longlived (years). Smaller plumes apparently have substantial amounts of associated SO_2 and eruptive temperatures of about 300 K while large plumes are depleted in SO_2 and erupt at nearly 600 K. Sulfur is believed to be the driving force for large plumes, whereas SO_2 in shallow reservoirs drives the small plumes. Plume distribution suggests global crustal asymmetries with the small plumes concentrated in an equatorial belt, while three large plumes are concentrated in the hemishpere centered on 300^o W.

D. C. Pieri, S. M. Baloga, and R. M. Nelson (Jet Propulsion Laboratory) reported on the colors of lava flows at Ra Patera on Io. On the basis of morphological and qualitative color observations, they have argued that long (> 150 km) sinuous, radially-oriented flows at Ra Patera are the result of the eruption of molten sulfur in a temperature range of 400 to 525 K. Detailed photometric data on the flows at Ra Patera show systematic trends consistent with a change to higher albedo allotropes as one moves away from the caldera. In a related study, Baloga, Pieri and D. L. Matson (Jet Propulsion Laboratory) investigated the characteristics of the bright, distinctive ribbon-like markings (auras) adjacent to many of the sulfur flows observed on Io. These authors attribute the formation of auras to volatile release activated by sulfur flows and, on the basis of theoretical and geomorphological arguments, and additional considerations such as degree of volatility, spectral properties, and chemical abundances, conclude that SO_2 liberation from the regolith beneath the flow is the most likely explanation for the auras at Ra Patera.

L. S. Crumpler and R. G. Strom (University of Arizona) have examined models for active volcanism on Io using heat-transfer models and have developed a unified model which suggests that most of the heat flow from Io is dissipated by advection, not conduction, and that the heat flow is modulated by the efficient transfer of heat from silicate melts generated at 100 to 200 km depth. The melts are injected at sulfur-silicate crustal interfaces, and interact with a sulfur crust about 2 km thick. For uniform global conductive heat flow, the prevailing temperatures at the base of the sulfur crust will be lower at polar latitudes which may explain the lack of observable plumes at the poles of Io.

A. F. Cook (Smithsonian Astrophysical Observatory) and colleagues E. Shoemaker, L. Soderblom, K. Mullins, and R. Fielder, investigated the possibility of volcanism in ice on Europa using a Voyager frame which exhibits a bright spot appearing at a contrast far greater than seen for any other feature on Europa. They believe that this area may be a site of active ice volcanism.

R. E. Grimm (University of Tennessee) and S. W. Squyres (NASA Ames Research Center) reported on spectral analysis of topography on Ganymede. Data collection and preliminary analysis have been undertaken in order to search for regional variations in groove spacing and morphology on Ganymede.

J. B. Plescia (Jet Propulsion Laboratory) and J. M. Boyce (NASA Headquarters) have compiled crater density statistics for the Saturnian satellites and have developed a theoretical cumulative flux history which suggests that the majority of satellites have ancient surfaces in excess of 3.8 billion years.

A. Ruzicka and R. Strom (University of Arizona) analyzed the spatial distribution of craters on the Moon and Callisto and found that their results, combined with those from Monte Carlo computer simulations, strongly suggest

that the Callisto (and Ganymede) crater population is a production population deficient in large craters relative to that of the terrestrial planets. These results indicate that the population of impacting objects responsible for the period of heavy bombardment in the inner solar system was different from that in the vicinity of Jupiter and that it may also have had a different origin.

J. H. Fink, R. Greeley (Arizona State University), and D. Gault (Murphys Center) examined the effect of crustal viscosity on impact cratering of icy satellites and have shown that relative age determinations of different surfaces on the icy satellites must take into account the possibility that craters subjected to viscous scaling laws would have different shapes and volumes than those controlled solely by gravity.

S. Squyres (NASA Ames Research Center) and C. Sagan (Cornell University) reported on studies of the very dark leading hemisphere and the very bright trailing hemisphere of Iapetus and proposed that the dark material on Iapetus is composed of organic chromophores produced from CH_4-rich ice and that ballistic diffusion may be responsible for the asymmetry.

The United Kingdom - Caltech Asteroid Survey reported on their ongoing efforts to establish accurate orbits for about 1000 faint asteroids.

F. Fanale and J. Salvail (University of Hawaii) described studies of the development of ice-poor/silicate-rich "mantles" or regoliths on cometary objects.

Venus

Venus studies continue to be of central importance to planetary geology. Currently we are dependent on Earth-based and Pioneer data. The kinds of models that might explain our current observations are being set up for testing by the Venus Radar Mapper mission.

Two major unsolved problems for Venus are the dominant mechanism of lithospheric heat loss and the origin of highland and mountainous terrain. Three end-member candidates for the principal mechanism of lithospheric heat loss on Venus are: plate recycling (as on Earth), conduction without lithospheric recycling (as on the smaller terrestrial planets), and hot-spot volcanism (as on Io). These end-member mechanisms lead to very different predictions of the detailed geological characteristics of highland, plains, and lowland units on Venus, but existing imaging and topographic information are at too coarse a resolution to discriminate among these possibilities.

Recent high-resolution Earth-based images of banded terrain in the mountain ranges of Ishtar Terra may help to constrain the tectonic evolution of this highland region and of Venus in general. As described by Head (Brown University) and Campbell (Arecibo Observatory), a tectonic origin is favored for the banded terrain. Solomon (Massachusetts Institute of Technology) and Head tested several models for the formation of the bands by compression (folding) and, alternatively, by extension (graben-horst or imbricate faulting). For both types of model, the spacing between adjacent bands constrains the thickness of the superficial elastic/brittle layer in Ishtar Terra to be no more than a few kilometers at the time of band formation. This value for the elastic lithospheric thickness on Venus, considerably less than on Earth, can be used with laboratory measurements of the mechanical behavior of rocks to constrain the thermal gradient in Venus highlands.

The high resolution (3-6 km) radar images of the mountains of Ishtar Terra obtained using the 12.6 cm wavelength system at Arecibo Observatory reveal the presence of numerous bands of high radar backscatter within the mountains. These bands are about 10-20 km in width and run parallel to the long axis of Akna, Freyja, and Maxwell Montes. Analysis of their spacing, continuity, and correlation with topography strongly suggests a tectonic origin for the bands and associated mountain ranges.

W.E. Elston (University of New Mexico) reports that tectonic plates on Venus are likely to be thin and ductile, in the absence of efficient cooling mechanisms (equivalent to terrestrial convecting oceans and atmosphere). Tectonic styles may resemble those of the Basin and Range province, where the continent underwent 100% ductile extension and uplift of several km, while being underplated by hot and ductile lithosphere (newly generated by a spreading center about to collide with the western plate margin). The result was massive partial melting of the continental lithosphere; shallow plutons blistered and burst to form hundreds of ignimbrite calderas tens of kilometers in diameter. Metamorphic core complexes ("turtlebacks") and low angle normal faults ("detachment faults") characterize the axis of this zone of "extensional orogeny".

Such conditions are not unique to the mid-Tertiary of North America. Other examples of massive lithosphere extension, thinning, and partial melting include modern back-arc basins and the proterozoic Pan-African thermal event. These are plate-tectonic styles that are not characterized by compressional mountain ranges, andesite arcs, and (in some examples) mid-ocean ridges and marginal trenches.

Venus may lack trenches, mid-ocean ridges, andesite arcs, and compressional mountain ranges and yet have its own style of plate tectonics. A cratered surface may not be evidence for dominance of impact processes. Volcanism may take forms different from those of Earth. For example, ignimbrites under the 700 K, 90 bar atmosphere of Venus may travel for long distances in a manner analogous to that of terrestrial canyon-cutting marine turbidites.

Cratering Processes

The session began with a presentation by D. E. Wilhelms (USGS - Menlo Park) on the geologic effects of the proposed lunar Procellarum basin. This basin, if real, would be at least 3200 km in diameter and encompass all the nearside lunar maria except Crisium, Fecunditatis and Nectaris. Wilhelms believes that excavation occurred out to the 3200 km diameter topographic rim, producing a shallow excavation cavity with a depth/diameter ratio between 1/37 and 1/64. The effects of this impact were to: 1) strip and remove primordial lunar anorthositic crust, thereby exposing underlying Mg-suite rocks (norites, troctolites, etc.) and KREEP; and 2) locally decrease the thickness of the lunar lithosphere, thereby concentrating the sites of mare volcanic eruption and regional tectonic deformation. Wilhelms suggests that other terrestrial planet dichotomies (e.g., martian hemispherical dichotomy) may be related to large basin impacts in early planetary geologic history.

P. D. Spudis (USGS - Flagstaff and Arizona State University) next presented the results of his study of the excavation of lunar impact basins. This study examined the petrology and regional composition of five basin ejecta blankets (Orientale, Nectaris, Crisium, Serenitatis and Imbrium) and combined these results with interpretations of regional crustal thickness and basin morphology to estimate the probable depths of basin ejecta derivation. Spudis finds that lunar basins excavate mostly crustal materials and in conjunction with morphologic analyses, suggests that basins excavate to depths about 0.1 times the diameter of the transient cavity, a feature which is about 0.6 times the diameter of the basin main topographic rim. These findings suggest lunar multi-ring basins form by structural modification of initially small transient cavities.

R. J. Pike (USGS - Menlo Park) discussed the morphologic transition from large craters to small basins on the Moon, Mars, Mercury, Ganymede and Callisto. He finds that this transition is characterized by a class of transitional large craters that

has a relatively small central peak and central-peak ring. Mature two-ring basins on the five planets studied have a 0.5 ± 0.05 ratio of inner and outer ring diameters whereas this ratio is only 0.4 ± 0.05 for the transitional large craters. The base diameters of central peaks is about 0.2 of the rim diameter for complex craters, but is much less where an inner ring is also present. Pike suggests this complementary relation indicates that the fraction of total impact energy consumed in making central structures remains constant with increasing crater size.

Volcanic Processes

A progress report on the thickness and distribution of volcanic materials on Mars was presented by R. DeHon (Northeast Louisiana University) who used buried craters to estimate the thickness of volcanic (and other) materials. The accuracy of the method is limited by the frequency of buried craters and quality of elevation data. No craters are preserved on Tharsis, Elysium, and Syrtis Major because volcanic materials are in excess of 1.5 to 2.0 km thick. Interpretation of data in the northern lowlands is uncertain because of questionable preservation of craters. Although the southern highlands have limited photomosaic coverage, they show a promise of reasonable estimates because of appropriate thickness of volcanic materials and crater record. Current estimates of thickness of volcanic materials on the ridged plains (primarily in the southern highlands) is 800 ± 300 m.

Detailed geologic mapping on high resolution Viking Orbiter photographs by E. C. Morris (USGS - Flagstaff) has identified the major stratigraphic and structural elements of the Olympus Mons shield volcano on Mars. The flanks of the volcano are covered by thin, low viscosity lava flows. The youngest flows have distinct lobate terminations, sharp boundaries, and appear fresh and pristine compared to the older flows on which they lie. Flows on the upper flanks and near the summit have rough, hummocky surfaces and predate the formation of the basal scarp of Olympus Mons. Blocks of the material upon which Olympus Mons rests dip inward towards the center of the volcano along the rim of the scarp. The complex nature of the scarp supports its tectonic origin by thrust faulting after compressional forces developed in the crust during subsidence of the volcano.

Mapping on Viking images by H. J. Moore (USGS - Menlo Park) has shown that the following volcanic features can be identified: 1) volcanic centers with small edifices, 2) lava flows on small volcanoes, 3) parasitic shields and deposits of flank eruptions from Arsia, Pavonis, and Ascraeus Montes. He mapped

the distribution of flows around the various montes and their centers and confirmed the general concordance between present topography and paleoslope inferred from some of the lava flows. Some lava flows suggest discordances between present topography and paleoslope. His study supports the conclusions of other workers on the relative ages of most of the volcanoes and craters. The heights attained by large volcanoes tended to increase with time, but eruptions at low elevations persisted throughout. Previously unrecognized channel deposits are probably fluvial but some may be glacial. Considerable quantities of water were released during the formation of Elysium Mons. Some of this water originated by melting of permafrost, but primordial water cannot be excluded.

Lava channels on the eastern Snake River Plain of Idaho were compared to similar lunar features by H. Economou and J. S. King (SUNY - Buffalo). These lava channels form where the margins of lava rivers or streams solidify to form low bounding levees. The levees become higher and wider with an increased flow in the channel. Thermal erosion occurred in the Inferno Chasm and Mule Butte channels. Features on the Moon and Mars that are similar to the Snake River Plains lava channels include: Schroters Valley, channels near crater Prinz, and channels issuing from the Elysium Mons summit caldera.

Pyroclastic deposits at Mount St. Helens were studied by C. W. Criswell and W. E. Elston (University of New Mexico) to determine if their surface features could be distinguished on high- and low-resolution planetary images. These small pyroclastic flows have several morphological features in common with other types of flows, including longitudinal ridges, transverse ridges, and small flow lobes. Primary features also include erosional channels and failure scarps. Where they encountered water some flows at Mount St. Helens were modified by

secondary phreatic explosion pits that resemble small bowl-shaped impact craters. Few of the above features increase in scale proportionally with the volume of the pyroclastic flows. This suggests that without an ability to resolve surface features smaller than 10 m, positive identification of ignimbrites by this technique alone may not be possible. Using these criteria, ignimbrite deposits tentatively have been identified on Io, but none have been recognized on Mars.

Pyroclastic flows produced during 1980 at Mount St. Helens were also studied by C. A. Neal and S. Self (Arizona State University). Although they too recognized no large-scale morphological features that would be useful for identification of pyroclastic flows on Viking or Mariner imagery, they believe that eventually it may be possible to recognize extraterrestrial pyroclastic flows on the basis of surface morphology. It appears that the development of surface features may be inversely related to volume of these deposits.

Experimental and natural products of hydroexplosions were investigated by M. F. Sheridan (Arizona State University) and K. H. Wohletz (Los Alamos National Laboratory). A second series of water/melt (thermite) experiments conducted at Los Alamos National Laboratory has determined that the optimum mass mixing ratio for explosive conversion of thermal energy to mechanical energy is about 0.5 for thermite and 0.3 for basalt. At optimum mixing ratios the particle size is very small (10-50 μm) but at greater or lesser ratios the diameter of the explosion product is larger. The shape of the particles produced by thermite explosions is variable (mossy, blocky, platy, and spherical outlines), but similar to those of hydrovolcanic pyroclasts. The intensity of surface alteration of grains produced by hydroexplosions is linked to the degree of water/melt interaction of the explosions. Models for dispersal of particulate materials produced by hydroexplosions depend on the ejection height, mobility of the flows (slope of the energy function), and the difference in elevation between the topographic surface and the energy surface.

Aeolian Processes

Research on planetary aeolian processes focused on several major topics during the last year: 1) analysis of martian aeolian activity on a global scale; 2) study of local aeolian activity on Mars; 3) understanding aeolian activity in a general sense; and 4) initiation of research on venusian aeolian processes.

A. R. Peterfreund (Brown University) conducted a search for local martian dust storms using a combination of visual and IRTM observations. 31 local dust storms were identified. In general, local storms seldom originate in areas that are inferred to have large dust deposits, but rather appear to begin in areas interpreted to be sandy -- a finding that is consistent with models requiring the presence of more readily movable sand-sized material to set dust into motion. An alternative model for dust-raising mechanisms involves injection of dust into the atmosphere by gas jetting. Studies by R. L. Huguenin and S. M. Clifford (University of Massachusetts) show that gas escape velocities up to 450 m/s are possible during rapid gas desorption from the upper few cm of soil when triggered by humidification of the soil.

Several investigators were concerned with the mechanism of wind streak formation on Mars. S. W. Lee, P. Thomas and J. Veverka (Cornell University) refined a model in which bright streaks are formed by preferential deposition of dust in the quiet, stratified air in the lee of an obstacle. The stable stratification occurs during dust storms and is due to increased atmospheric heating and a corresponding drop in the surface temperature because of the airborne dust. They found that obstacles with heights of tens to a few hundred meters are efficient producers of bright streaks; however, the prediction that the streak length/obstacle height ratio would remain constant with increasing obstacle height was not supported by observation. The ratio was seen to decline with increasing obstacle height, implying that smaller obstacles are more efficient at streak

production than larger ones. J. D. Iversen, R. Greeley and J. B. Pollack (NASA - Ames Aeolian Consortium) performed wind tunnel experiments to test the obstacle method of wind streak formation and found it to be a viable process. Wind streaks are an important indicator of aeolian activity, both for the occurrence of particle motion and as a "wind vane" for determining wind directions. R. Greeley and colleagues at Arizona State University have found wind streaks longer than 15 km on radar images (SIR-A) on Earth, demonstrating the possibility that wind streaks could be detected on Venus by the Venus Radar Mapper.

M. Mainguet and C. Moreau (Université de Reims, France) described aeolian dynamics of the north circumpolar sand sea on Mars. Based on the morphology of dunes in that area, they conclude that the erg is young and still growing. The height of the transverse dunes indicates that the climate has been stable for a long time, but the presence of sand ridges indicates the sand system is evolving.

Aeolian activity at the martian Mutch Memorial Station (VL-1) was reported by H. J. Moore (USGS). One of the piles of fine-grained drift material created by the lander sampling arm showed aeolian modification. The change probably occurred between Sols 1601 and 1765, near the winter solstice when strong northerly winds are expected to occur. Moore attributes the change to saltation impact or entrainment of "clodlets" of pile material, rather than individual grains which apparently are very fine (0.14-2 μm diameter). E. A. Guiness and R. E. Arvidson (Washington University) have developed a new method for detecting contrast changes (presumed to be the result of aeolian activity) at the Mutch Memorial Station. Their technique is to digitally compare two images of the same area under similar lighting conditions.

One of the main objectives of studying planetary aeolian processes is to derive a unified, general understanding of the causes and results of aeolian activity and to be able to predict potential aeolian activity. A computer program

is currently under development by R. Greeley that simulates the two-dimensional abrasion of a rock by windblown particles. The program is interactive and allows the rock composition (abrasion resistance), rock initial shape, impactor size and composition, and wind speed to be varied. The goal is to predict the morphology of ventifacts on Earth, Mars and Venus.

A high-pressure wind tunnel capable of operating at venusian atmospheric densities was constructed at NASA-Ames under the leadership of R. Greeley. The tunnel is being used to extend the theoretical predictions for saltation threshold, particle trajectory, and flux of saltating material to Venus. The theoretically predicted saltation threshold was confirmed to apply to venusian atmospheric density. High-speed motion pictures of saltating particles in the Venus Wind Tunnel were analyzed by B. R. White (University of California Davis) to derive numerical solutions to the equations of motion for a saltating particle. It was found that the trajectories will be much lower and shorter on Venus than on Earth and Mars, for similar dynamic conditions. Particle spin was found to be an important factor in the saltation trajectory, as it is on Earth. S. H. Williams (Arizona State University) found that the saltation flux equations of White apply to venusian atmospheric density for particles of 100 μm but may not be appropriate for particles of different size or density.

General conclusions are that aeolian processes probably do occur on Venus under present wind conditions and that Venus has the potential to move large quantities of material long distances over geologically short periods of time.

Fluvial Processes and Landform Development

Studies of martian channels and valleys have matured considerably in the decade since these features were first discovered. Overly simplistic hypothesizing about which fluid to invoke for channel formation has now given way to creative modelling of probable genetic processes and detailed imagery analysis to test the models. While some work continues on outflow channels, the emphasis of recent research has shifted to the valley networks. The latter are most likely to be indicative of ancient compositional and climatic conditions of an evolving martian atmosphere.

M. H. Carr (USGS - Menlo Park) is attempting to assess the paleoclimatic implications of the valley networks by calculating the freezing rates of flowing water at various possible surface temperatures and pressures. In contrast to earlier calculations by other investigators, Carr finds that even relatively shallow water flows (0.5 to 1.0 m deep) can persist at reasonable gradients for considerable distances (100 km) under the present atmospheric conditions. Thus, provided that the water flow can be initiated, Carr's model suggests that it is not necessary to postulate warmer and/or denser ancient atmospheric conditions on Mars to explain the valley networks.

Mapping studies of channel and valley development are under way by several investigators. V. R. Baker (University of Arizona), G. R. Brakenridge (Dartmouth) and R. C. Kochel (University of Virginia) have used detailed geomorphic mapping of the valleys in heavily cratered martian uplands to illustrate the complex morphogenesis of those regions. Valleys show structural control, inversion of topography, superimposition on craters, and extensive modification by mass movement, thermokarstic, and eolian processes. Clearly future studies need to combine the Mars mapping studies with various genetic models to generate a picture of atmospheric evolution on the planet consistent with the observed record of an operating hydrologic cycle.

J. C. Boothroyd (University of Rhode Island) has also found that detailed geomorphic mapping can be very useful in deciphering the complex fluvial history of Mars. Using stereo pairs of Viking Orbiter images and Earth-based radar profiles, Boothroyd mapped drainage basin boundaries in the Margaritifer Sinus region. This region is an interesting transition zone between valley networks and outflow-related chaotic terrain. Preliminary results indicate that some valley networks were tributary to very ancient outflow channels, while others flowed into depositional basins. Networks were locally beheaded by the development of chaotic terrain or mantled by crater ejecta and/or eolian material. Mantled networks were subsequently reactivated.

D. H. Scott (USGS - Flagstaff) has found unusual sinuous features in the Chryse Planitia, especially in the lower course of Ares Vallis. He compares Viking images of these landforms to the meandering patterns of terrestrial rivers. Unlike terrestrial meanders, however, the martian landforms have ridges in the centers of their floors at many localities. The recognition of these landforms far into the northern plains can be used as an indication of the former presence of running water in several regions where not previously recognized.

The Valles Marineris, once, during a more fluvial epoch on Mars, may have contained water in permanent or ephemeral lakes, and received sediment that was deposited in the interior. B. K. Lucchitta (USGS - Flagstaff) supports the former existence of these lakes or playas by several observations. Foremost is the evenly layered stratification of interior deposits. Also, the uniform elevation reached by the deposits in Ophir and Candor Chasmata, despite uneven floor elevations, suggests that they were deposited at a common base level, which indicates fluvial or lacustrine activity. Faint valley networks, above tributary canyons on the surrounding plateaus, suggest that runoff took place. A difference in wall morphology between old wall segments supporting spurs and gullies, and

young, smooth wall segments may indicate climatic change and a former more fluvial epoch. Simud and Tiu Valles, which are connected to the Valles Marineris drainage system, are deeply incised beneath the surrounding plateau surface and have near level gradients. These observations suggest that Simud and Tiu were eroded vigorously by fluids with a large head of water. Lakes, which were breached by headward erosion and then emptied catastrophically, could have furnished the water for such intense erosion.

Alan D. Howard and Charles McLane (University of Virginia) are investigating the process of groundwater sapping by a combination of experimental, theoretical, and simulation approaches. Experiments in a narrow groundwater flow tank confirm the linear relationship between sapping rate and excess hydraulic gradient. Finite-element flow models are being used to calculate detailed flow nets that can be compared to piezometric measurements made during the experiments. Simulation modelling will be used to test the development of dendritic valley networks by a process of "groundwater capture" in which an extending network gains a competitive advantage over other networks. Various models are compared to theoretical studies of the mechanics of the sapping process.

In another study of the sapping processes, R. C. Kochel (University of Virginia), V. R. Baker (University of Arizona), D. W. Simmons and C. J. Lis (SUNY - Fredonia) used a laboratory analog model. The morphometry of networks developed in this model was then quantitatively compared to terrestrial runoff systems and to martian valley networks tributary to the Valles Marineris. The model consisted of a sapping chamber about 1.3 m^3 which simulated network development in fine sand. The study revealed many similarities between network morphometries on Mars and in the sapping box. These include: relatively low junction angles ($\overline{X} < 40^0$), high ratios of main channel length to tributary length, change of junction angle down-network, and highly variable relationships among various morphometric parameters. These results are quite different than measurements reported for terrestrial runoff systems.

Paul D. Komar (Oregon State University) reports that an investigation is underway employing spectral analysis techniques to examine the meandering or sinuosity of river channels and other terrestrial channel-like features (lava tubes, lava channels, etc.). These will be compared with similar analyses of simuous martian channels in order to discern their origins, and in the case of those formed by water, estimate the responsible discharge.

To date the study has focused on the rivers utilized by Leopold and Wolman (1960) to establish a relationship of meander wavelength versus flow discharge. Their data are not entirely consistent with other data sets, and this may be due to the subjective nature of the traditional methods for selecting one representative meander length. It is anticipated that the spectral analyses will aid in this selection, making it both more systematic and repeatable. The spectra of sinuous rivers within rocky terrains are also being studied in an attempt to discern the effects of local geologic structure as well as channel formation processes. This aspect of the study will be especially important in the determination of the mode of formation of the sinuous channels on Mars.

The various fluvial studies reported here have benefitted from the activities of the Mars Channel Working Group. Meetings of the working group have resulted in a consensus among investigators concerning the fluvial origin of channels and valleys on Mars. The report of the group, entitled, "Channels and Valleys on Mars," is soon to be published by the Geological Society of America Bulletin.

Remote Sensing

The remote sensing session covered aspects of three major areas of planetary geology: digital image processing techniques, use of multispectral data in mapping and rock type identification, and the utility of microwave sensing in mapping surface and subsurface characteristics of Mars and of Earth's hyperarid regions.

Philip A. Davis and colleagues (USGS - Flagstaff) discussed an interactive technique for extraction of topographic profiles from digital Viking Orbiter frames. The technique is based on removing an offset due to skylight and then ratioing two brightness profiles extracted from the image. For symmetrical features, such as craters, the ratio of two profiles drawn from the crater centers to the rims tends to remove albedo effects and leave information related to slope. Use of a photometric function then allows the analyst to extract the topographic profile, construct a synthetic image of the crater, and compare the real and synthetic data for differences. If the match is poor, the user can choose an alternative function or change the profile locations until better results are obtained. Asymmetrical features can also be dealt with if a flat surface can be identified and if both albedo and slope variations can be modelled.

John F. McCauley and colleagues (USGS - Flagstaff) highlighted the results from the SIR-A (Shuttle Imaging Radar-A) images over the hyperarid eastern Sahara desert. The SIR-A instrument used 24 cm radar and a depression angle of 43^{o}. The data indicate that the radar signal penetrated beneath the dry sands of the Selima sand sheet and encountered alluvium filled valleys. The calculated depth of penetration, because of the dry conditions, could be as high as 5 meters. Thus, a sequence of relict valleys, perhaps as old as middle Tertiary, have been mapped. The electrical properties of the materials are similar to those expected for martian materials. Thus, an imaging radar instrument in orbit about Mars would likewise be able to map subsurface features such as relict deflation surfaces

or ancient alluvium deposits. Such data might prove invaluable for understanding the origin and evolution of the northern plains that appear fairly featureless in Viking Orbiter photography.

Richard Simpson and colleagues (Stanford University) presented an update on the Viking Orbiter bistatic radar experiments where 13 cm wavelength radio signals were transmitted from the Viking Orbiter antennas, reflected off the martian surface, and received on Earth. Using the Hagfors scattering law they present data pertaining to surface tilts. They find little correlation between the appearance of terrain on Viking Orbiter photography and the radio scattering characteristics of the surface. One explanation is that features seen on Orbiter photography are controlled by different processes than those whose characteristic wavelength is comparable to or somewhat larger than the radio wavelength used.

Raymond E. Arvidson and Edward A. Guinness (Washington University) used Viking Orbiter red/violet images, albedo, thermal inertia data, and high-resolution Orbiter images to search for correlations between color and albedo (10's to 100's m depth), thermal inertia (10's cm) and morphology (m). For Arabia and surrounding areas, they identified clusters based on a triangle plot of color, albedo, and thermal inertia. The clusters were driven by variations in thermal inertia, while color and albedo data were more variable. The region with the highest thermal inertia was found to be the brightest, reddest area, and one mantled with debris, based on the presence of buried craters.

Finally, B. Ray Hawke and colleagues (University of Hawaii) reported on new spectral reflectance data fro the Schickard-Schiller region in the lunar terrae (40 to 60^{o} S; 35 to 68^{o} W). They find that dark haloed craters have a basaltic signature, suggesting that these craters penetrated beneath Orientale ejecta deposits, excavating pre-Orientale mare volcanic deposits. They also suggest that the Schiller plains, which have a lower albedo and crater density than the surrounding terrae light plains, may have formed by post-Orientale mare volcanism.

Permafrost, Volatiles and Regolith Studies

Papers in this session dealt with a variety of observations and facts derived from terrestrial observations and laboratory investigations designed to permit hypotheses to be formulated on the properties and behavior of cold, planetary regoliths.

D. M. Anderson (State University of New York at Buffalo) presented a comprehensive review of data on the physical and mechanical properties of terrestrial permafrost presented in formats that permid ready extrapolation to planetary permafrost as it exists in the various cold planetary environments. New calculations on the depth of permafrost on Mars were presented. Depths greater than those derived from earlier, more conservative computations are indicated. The proportion of ice to adsorbed, interfacial water that remains unfrozen at low temperatures was illustrated as it varies with temperature for a variety of terrestrial permafrost constituents. The dependence of the unfrozen water contents on grain size (specific surface area) was emphasized and related to the strength and deformation characteristics of frozen ground. Primary, secondary and tertiary creep was illustrated and discussed. Permafrost at temperatures ranging from -5^{0} to -100^{0} C and lower has the strength characteristics of weak concrete except for its creep characteristics which are distinctive. Grain size, ice content, pressure, temperature, and the presence or absence of salts are the primary factors governing the characteristics of permafrost. Water may move through permafrost by molecular diffusion or by restrained hydraulic flow. It moves within the extended network of unfrozen, interfacial films. Water migrates along temperature gradients from warm to colder regions where it crystallizes and is capable of developing enormous pressures. Pressures in excess of several hundred atmospheres have been observed in laboratory simulations. Localized crustal deformations of planetary surfaces due to this phenomena must be expected, superimposed on the crustal features of larger scale resulting from tectonism.

Calculations based on the Viking Mission data indicate that permafrost thicknesses range from abut 3.5 km at the martian equator to approximately 8 km in the polar regions. The depths to the bottom of martian permafrost are more than three times the depths characteristic of permafrost in terrestrial polar locations. Martian permafrost is much colder than terrestrial permafrost and it must, consequently, be much stronger. Because of the lower temperatures, the proportion of unfrozen water to ice must be much lower in general, but this may be somewhat counteracted by the generally higher salinity of martian permafrost. The combination of low temperatures and great thicknesses of martian permafrost, coupled with the low atmospheric pressure and the very low precipitation (snowfall) enhance the current stability of the martian surface. The "active layer" on Mars (the layer that alternately freezes and thaws with seasonal changes) is extremely thin compared to that of terrestrial permafrost making martian permafrost very resistant to erosion compared to the situation presently existing on Earth.

S. M. Clifford (University of Massachusetts) presented an extremely intriguing and important possibility. First, the term, "basal melting" was discussed thoroughly and taken to include any situation where pore ice or glacial ice is melted beneath a glacier or ice sheet. The conservative estimates of permafrost depth of 1 km at the equator to about 3 km at the martian poles derived from the work of Fanale (1976), Rossbacher and Judson (1980), together with recent estimates of the total inventory of water on Mars, then served as a basis for a series of thermal calculations. An important conclusion was that there exists a sizable reservoir of martian ground water. The computations indicated that from 1.2 to 7 km of polar ice is required for geothermal melting at its base, depending upon the dust content and the possibility of salts being present.

The regime of the polar ice sheets was then described in qualitative terms. Because of the strong possibility of large reservoirs of ground water on Mars, it was earlier suggested by Clifford that Chasma Boreale might have been formed by catastrophic releases of reservoirs of glacial melt water. It was pointed out that this suggestion is consistent with the calculated depths for basal melting resulting from the computations just presented. Morphological similarities between Chasma Boreale and other similar features on Mars were discussed. Attention was called to terrestrial occurrences of subglacial lakes and the occasional catastrophic releases of sufficient quantities of water to produce large erosional features. Finally, reference was also made to the general hydrological cycle that may be characteristic of Mars, highlighting the potential importance of the phenomena of polar basal melting.

M. Coradini and colleagues (Instituto di Astrofisica Spaziale) dealt with some interesting laboratory experiments involving the measurement of transitory and remnant magnetic fields that accompany hypervelocity impacts. Ferromagnetic concrete targets were chosen to provide both an appropriate mechanical, as well as an isotropic magnetic response. Experimental conditions were arranged so that the projectile mass, as well as its velocity, could be measured after impact. Measurements of the remnant magnetic field as it was observed at the surface of the ferromagnetic concrete target were carried out. From the results, elaborate maps of remnant magnetism were constructed. Preliminary analysis has revealed reasonably consistent results for all of the targets examined to date and show a characteristic trend for both the vertical and horizontal components of the magnetic field. In general, the magnetic lines of force are concentric around the point of impact and the resulting crater. Possible formation mechanisms of the magnetization induced by these hypervelocity impacts were discussed. Several mechanisms are possible and present evidence is not sufficient to choose definitively among them. Sufficient evidence was presented

to suggest that lunar magnetism could be due to the cumulative effects of hypervelocity cratering, although a portion of the remnant lunar magnetism may also represent a primordial ambient field.

J. L. Gooding (NASA Johnson Space Center) proceeded from the hypothesis that reaction of rocks and rock materials with hot, high pressure atmospheres rich in CO_2 has probably been a significant ongoing process on both Mars and Venus. Experiments were described in which a powdered crystalline basalt was subjected to a hot, high pressure H_2O - CO_2 atmosphere. The experiments were done under simulated martian conditions (conditions which might be expected to have occurred on Mars during impact cratering or during magmatic intrusion into a volatile-rich regolith). The powdered rock was subjected to a total gas/vapor pressure of 100 atm and a molar ratio H_2O/CO_2 of about 9 at a temperature of 350^{o} C for 48 hours. Such conditions correspond to a depth of about 900 to 1400 m in the martian regolith and a gas composition compatible with suggestions by Fanale and Cannon (1974) for adsorbed H_2O and CO_2 with additional H_2O corresponding to about 0.5% water ice in the regolith.

The powdered rock became spectrally darker at a rate which was about twice that previously observed in a similar dry carbon dioxide experiment. The darkening was ascribed to the oxidation of iron-silicates to a form containing Fe_3O_4. Significant quantities of hydrous minerals were not observed, however, and it was inferred that they did not form. It was concluded that impact produced or volcanically induced hydrothermal alteration on Mars probably is significant only if exposure of the rock materials to hot, volatile fluids is sustained for relatively long periods of time. It was concluded that the essentially instantaneous alterations proposed speculatively by some previous workers appear to be unlikely.

Since the publication of the results of the Viking X-ray fluorescence measurements, there has been much speculation regarding specific minerals that

may be present in the martian regolith. Because of the large quantities of dust observed in the martian atmosphere, in addition to the characteristics of the surface material on Mars inferred from observation of the trenches dug by the Viking spacecraft sampling arm, the presence of clay minerals has been widely assumed. On the basis of spectroscopic measurements, the clay mineral nontronite has been widely adopted as a terrestrially occurring clay mineral that can serve as a good analog for the clay minerals that must be present on Mars. A. Banin and L. Margulis reviewed the list of clay minerals that has been compiled since 1976 and discussed the dissimilarities and difficulties that can be cited to disqualify or render many of them less than likely martian analogs. All the observational data and criteria available were then applied to the mineral palagonite and it was concluded that palagonite should be seriously considered for inclusion in the selection or adoption of terrestrial analogs of the constituents of martian soils.

E. K. Gibson (NASA Johnson Space Center) and colleagues presented an account of observations and data taken on samples of Antarctic soils collected during the 1979-80 astral summer. The dry valleys of Antarctica have earlier been recognized as comparable in many respects to features on Mars and the soil development processes have been taken as similar in many wasy to the processes now operating on Mars. Cold, arid regions nearly always have high concentrations of soluble salts in soils that have developed there. Ugolini (University of Washington) and his colleagues developed the baseline data on the saline soils of the dry valleys of the Antarctic many years ago. The results have appeared in the Antarctic Journal of the United States and in Proceedings of the Second and Third International Permafrost Conferences, published by the National Academy of Sciences/National Research Council. This paper adds to that database and confirms earlier findings and conclusions. With the availability of detailed compositional data from the Viking landers, additional comparisons are made possible; this paper dealt with many of these.

The possibility of the formation of zeolites on Mars was one of the highly intriguing questions posed as a result of this work. Zeolites are well known for their ability to entrap and immobilize gases until heated. Consequently, they might be expected to be a repository of ancient atmospheric gases, dating from very early times. The possibility of such a reservoir would be an important factor in the consideration of atmospheric phenomena on Mars. It would also be very interesting if in future Mars lander missions data on gases retained by zeolites found in the martian regolith could be sampled and analyzed.

R. S. Saunders (Jet Propulsion Laboratory) and colleagues discussed results obtained from a large, elaborate low-pressure chamber designed to simulate martian soil/atmospheric conditions. The Martian Environmental Simulator is located at the Jet Propulsion Laboratory in Pasadena, California. Earlier results pertained to atmospheric and soil interactions under isothermal conditions. This work dealt with the behavior of dry martian soil in a CO_2 atmosphere under characteristic martian pressure and temperature regimes. The propagation of a thermal wave was followed in soil at -50° C over a period of several weeks. The energy imparted to the soil corresponded to a characteristic martian solar equivalent. The thermal conductivity of soil under these conditions was observed to be strongly dependent on CO_2 pressure over a range typical of variations in the martian atmosphere. The thermal wave was observed at a depth of one meter after four weeks. Plans for following a pressure wave as it is propagated through the soil material were described and suggestions for additional experiments were invited from an interested audience.

Geomorphology, Structure and Stratigraphy

P. C. Patton (Wesleyan University) discussed how the morphology of the spur and valley topography that is developed on the wall scarps of the Valles Marineris can be quantitatively described. The descriptive process is similar to the process used to identify drainage networks on Earth. These descriptive data can then be used to infer those processes that might be significant in controlling the geomorphic evolution of the scarps.

One study area, Candor Chasma, illustrates the research approach and the results from this chasma suggest one possible mechanism for the evolution of the scarp morphology. The northern wall of Candor terminates against a basal scarp, interpreted as a fault scarp, whereas the southern wall has no visible basal scarp. On the northern scarp there is a higher frequency of the smallest furthest downslope unbranched first-order spurs than on the southern wall. The mean length of the northern first-order spurs is shorter than the spurs with the same network position on the southern scarp. The interpretation is that the downslope spurs on the southern scarp are being buried beneath talus produced further up the scarp. In contrast the basal scarp on the northern side of Candor has created a lower base level which serves to drain from the slopes and enhance the erosional topography of the scarp. The spur and gully topography appears to be related to mass wasting phenomena and the ultimate form is a function of processes acting at the slope base.

In contrast, scarps in fluvially dominated terrains on Earth exhibit the opposite trend. The older and more degraded a tectonic scarp on Earth, the more finely textured and dissected the scarp appears. This is because in these environments removal of regolith is more efficient. Because the evolution of the martian scarps is controlled by dry mass wasting with limited transport processes the slopes become smoother and more dominated by depositional processes with time.

D. Nummedal (Louisiana State University) documented striking similarities between both scale and morphology of terrestrial continental slope erosional features and channel-related terrains on Mars. In terms of length, width, depth and cross-sectional profile the major submarine channels on Earth correspond to the outflow channels on Mars. Meandering channel floors, scalloped margins and longitudinal ridging are common features in both systems. Numerous large submarine slides correspond in scale and juxtaposition of environments to the chaos-outflow channel systems in the Chryse Basin on Mars.

The primary reason for the morphological similarity between the submarine slope on Earth and the channel-related terrains on Mars appears to be their common mode of sediment movement: mass movement. In subaerial terrestrial environments mass movement is subordinate to sediment transport by wind and running water. In submarine slope settings, however, mass movement dominates.

T. A. Maxwell (Smithsonian Institution) discussed research involving the analysis and distribution of ridge systems on the inner planets. This research has concentrated on detailing the local, regional and possible global influences that created these compressional features. Effects such as underlying craters localize compressional stress on the overlying plains, thus forming ridge rings. Regional systems of ridges within planetary basins and surrounding the Tharsis bulge on Mars result from both underlying structure and compression. Estimates of global shortening can be made only when these factors are subtracted from the total population. Using a folding model for N-S oriented ridge systems in the center of lunar basins, total E-W shortening on the Moon may be as little as 500 m, corresponding to a 70-meter decrease in lunar radius. This value may be increased as much as two orders of magnitude if compressional features at the edges of the basins are included.

P. G. Thomas and Ph. Masson (University Paris-Sud) discussed the fact that despite their morphologic similarities, Orientale, Caloris and Argyre basins show important differences due to external factors (martian erosion) and to internal evolution (crustal and lithospheric properties). The three basins are surrounded by concentric scarps, usually interpreted as gravity slumping downward and inward toward the transient cavity. Importance and distribution of the scarps differ in the three basins. The outer scarp of Orientale and Caloris do not show related tectonic features, but the Caloris ejecta exhibit uplifted and downward blocks indicating important tectonic movements. Argyre interior is completely embayed by recent plains material and does not show any tectonic features. The Orientale interior shows tectonic features produced by compressional stress during the final stages of crater formation. Caloris' floor is intensively ridged and fractured by tectonic movements possibly due to basin radius shortening under global compressive stresses of the mercurian lithosphere.

R. Bianchi and colleagues (Istituto de Astrofisica Spaziale) presented work on the different types of stresses which have disturbed the surface of Mars, producing extensive and compressive tectonic features. The fracturing modalities in the region Tharsis-Valles Marineris can be related both to the possible stresses caused by the ancient mantle movement and to the load of the volcanic material on the surface. In order to attempt a preliminary distinction among fracture systems in a more significant direction they statistically examined 6,723 fractures in the region limited between 170° and 40° longitude and $\pm 50^{\circ}$ latitude. The frequency distribution of azimuths for the fractures (grouped in 45 classes of 4° each) was computed in order to group the azimuthal values in very narrow angular trends; the angular interval was chosen to be just larger than the instrumental error due to the digitizing operation, $\pm 3^{\circ}$. Gaussian distributions were fitted to the peaks in the fracture azimuths

histogram obtaining several directional families. Assuming the mean value of each gaussian curve as the statistically significant orientation they extracted the fractures belonging to each directional family. Examining the geographical distribution of these fractures it is possible to choose the areas in which each direction is widely represented. These areas can be examined individually in order to find out the relations between the spacing among fractures oriented in each direction. They examined the fracture systems in the Claritas region where for each chosen direction it was possible to compute the distribution of mutual distances between contiguous fractures. The spacing between contiguous fractures for some directions on Claritas appears to increase moving from north to south. The different spacing between fractures could be related to different modalities of fracturing, due either to differing types of stress during the history of the planet, or to the differing thicknesses of the fractured crust. In attempting to correlate different fracture systems in order to determine the temporal sequence of fracturing events they saw that the younger directions are generally characterized by a wider fracture spacing. This could also be related to the different fracturing modalities mentioned earlier. They conclude that from a statistical analysis of the different spacing between fractures over a wide range of significant directions, it is possible to gain information on fracturing modalities and on the temporal sequence of fracturing events in areas where the fracture pattern is very complex (e.g., Labyrintus Noctus). This approach should be considered as a new starting point to interpreting the tectonism in Tharsis-Valles Marineris region.

D. H. Scott (U.S. Geological Survey - Flagstaff) reported that geologic mapping of Mars from Viking images has allowed a much greater subdivision of highland rock units than previously recognized on Mariner pictures. In places,

boundaries between units are not sharp contacts but represent gradational zones, although the end members of units are individually distinguishable. In several areas, mare-like wrinkle ridges are shown to be consistently older than the smooth plains surrounding them. The ridges may belong to an older ridged plateau unit subsequently partially buried by later lava flows. The oldest appearing martian rocks occur along the southern part of Claritas Fossae (30^{0}S, 100^{0}W). This basement complex is gradational in places with other units, particularly the hilly plateau and fractured plains materials.

Planetary Mapping

Planetary mapping (topographic, cartographic and geologic) is an important tool for planetary studies. R. M. Batson (U.S. Geological Survey - Flagstaff) reported that in the planetary cartographic program, the surface of 14 planets and satellites including Mars, Venus, Mercury, the Earth's Moon, four jovian satellites (Io, Europa, Ganymede and Callisto) and six saturnian satellites (Mimas, Tethys, Dione, Rhea, Iapetus and Enceladus) have been mapped from space data. Of these bodies, 11 were mapped from digital television pictures that have almost negligible potential for measuring topographic elevation; only the data sets for the Moon, Mars and Venus can be used to perform extensive contour mapping.

In 1982, the cartographic products from the Planetary Section of the Branch of Astrogeology, U.S. Geological Survey, are the publication of 37 new maps which include 25 controlled photomosaics of Mars at 1:2,000,000, 4 revised shaded relief maps of Mars at 1:5,000,000, a shaded relief map of the Chryse basin at 1:5,000,000 and maps of six saturnian satellties. A total of 99 1:2,000,000 controlled photomosaics of Mars have been published, another 12 are in press, and the remaining 29 are in various stages of completion.

A new series of controlled photomosaics of high resolution pictures of Mars is being compiled at 1:5,000,000 on a Mars Transverse Mercator projection system. The first sheets in the series to be compiled are in the Valles Marineris region. A preliminary albedo map of Mars has been completed with the light source elevation equal to 70^0. Small-scale planetwide maps of the 14 mapped planets and satellites are being prepared. They will be on conformal and equal-area projections which will be suitable for page-size publication.

For the control of photomosaic maps, M. E. Davies (Rand Corporation) has established a planetwide control network of Mars. The control net consists of 6,853 control points derived by analytical photogrammetric methods from 1,054 Mariner 9 pictures and 757 Viking pictures. It involved solving 19,139 normal equations and had a 18.06 μm standard error of measurement in the adjustment.

The establishment of control networks for the satellites of Jupiter and Saturn has been continuously progressing as listed in the following tables:

Control Networks of the Satellites of Jupiter

Satellite	Io	Europa	Ganymede	Callisto
# Pictures	240	120	295	240
Std. Error (μm) of Measurement	12.4	11.9	21.4	18.0
# Points	598	174	1,669	597

Control Networks of the Satellites of Saturn

Satellite	Mimas	Enceladus	Tethys	Dione	Rhea	Iapetus
# Pictures	32	22	27	28	84	80
Std. Error (μm) of Measurement	13.4	19.2	12.2	13.9	13.6	12.3
# Points	110	71	110	126	351	62

The control networks for the satellites of Saturn are considerably smaller than those of Jupiter, because of the smaller size of the satellites.

The satellite Mimas is ellipsoid in shape having 200.3 km, 195.8 km and 194.3 km respectively for its two semimajor axes and semiminor axis. Its mean radius is 196.8 km. Enceladus has a mean radius of 251.0 km with equatorial radii of 255.6 km and 249.5 km and a polar radius of 247.6 km.

Topographic mapping of extraterrestrial bodies differs in many ways from the mapping of Earth. It involves the solving of many unprecedented problems. In the absence of a natural equilibrium surface, the most appropriate method for establishing a topographic datum for a planetary body is to use its gravity field. S. Wu reported that based on their gravity fields, topographic datums for the Moon and Mars have been defined. All topographic maps of the Moon and Mars are based on such defined datums. A global topographic map of Mars was compiled between 1971 and 1975 using Mariner 9 spacecraft data and Earth-based radar data. This map is currently being upgraded using Viking Orbiter photographs. Large-scale

detailed maps of Mars can be systematically compiled by photogrammetric methods on analytical plotters. 13 of the 1:2,000,000 series maps have been completed. Also in preparation for formal publication is a topographic map of Olympus Mons.

To support compilation maps of Mars, a planetwide control network is being derived using up to 900 Viking Orbiter photographs. The adjustment also includes Earth-based radar data and occultation points from both the Mariner 9 and Viking missions. The control network is expected to be completed in FY 84.

By synthesis of topographic information derived from Apollo and Lunar Orbiter photographs, laser altimeter data, lunar radar sounder and Earth-based measurements, a global topographic map of the Moon is being compiled. An intermediate product is the series of contour maps LOC-1, -2, -3 and -4 of the Moon which were compiled using 566 stereo combinations of all available metric photographs from the Apollo 15, 16 and 17 missions. These four maps are in the review process for formal publication.

By using radar altimeter data obtained by the Pioneer Venus spacecraft, a global topographic map of Venus has been compiled using nonphotogrammetric methods. For the compilation of more detailed maps of Venus, the technology of using side-looking radar stereo images is under development and has progressed to the point where the radar layover problem can be corrected. The solution of the radar layover problem can be a new concept for the future design of radar stereo plotters.

The global geologic mapping of Mars was reported on by R. Greeley (Arizona State University). The NE quadrant of the geological map of Mars is in manuscript form which is part of the program involving D. Scott (U.S.

Geological Survey - Flagstaff), R. Greeley, J. E. Guest (University of London), and J. King (State University of New York at Buffalo). The new mapping shows considerably more complexities within the various regions although in general there is not very much difference from the mapping based on the Mariner 9 data. Draft copies of the equatorial region (65° N to 65° S) should be completed by the fall of 1983.

N. E. Whitbeck and J. R. Underwood Jr. (Kansas State University) discussed the local geologic mapping of Mars. The lava flow material on the mottled plains in Mare Acidalium quadrangle (MC-4) was illustrative of how recent geologic mapping has revealed evidence of relatively recent volcanic activity in the central region of Mare Acidalium, at about 47° N and 25° W. The evidence for volcanic activity includes the identification of several lava flow lobes, possible pressure ridges, and numerous small, mound-like domes that resemble cinder cones. The identification of volcanic features in this region is important because it proves that at least this part of the mottled plains has been resurfaced by younger volcanic material.

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16. Abstract

Recent developments in planetology research as reported at the 1982 NASA Planetary Geology Program Principal Investigators meeting are summarized. Important developments are summarized in topics ranging from solar system evolution, comparative planetology, and geologic processes active on other planetary bodies, to techniques and instrument development for future exploration.

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